APPENDIX B
DESIGN CONSIDERATIONS

1. Scope. Elements discussed in this technical letter include principles of operation, predesign studies and reports, design and performance requirements, construction planning and preparation, regulatory requirements, construction activities and management, operation and monitoring of the unit, and closure of the site. This document will focus on onsite thermal desorption technology. However, the principles of operation and critical operating parameters may also be applied to offsite thermal desorption technologies.

2. Background. Thermal desorption has been used to treat contaminated material containing organic compounds and other organic contaminants since the early 1980s. A thermal desorber is designed to separate organic compounds from soils, sludges, sediments and debris (typically after dewatering) by the application of heat. Thermal desorption is a treatment technology which is typically appropriate for remediation of petroleum and some PCB contaminated materials. Materials principally contaminated with toxic metals are not amenable to thermal desorption due to the partitioning and/or volatilization of metals with the process components of the thermal desorption system. The contaminated material is heated (directly or indirectly) to a sufficient temperature to evaporate the volatile compounds from the solid matrix into an off gas stream.

Incineration, on the other hand, is a combustion process that utilizes rapid oxidation, excess air and high temperature to produce a condition whereby waste constituents are thermally broken down and destroyed.

In the mid 1980s, thermal desorption increased in popularity because it was a thermal technology that provided similar technical benefits to incineration without the regulatory and public relations problems associated with the use of incinerators at waste sites.

Thermal desorber technologies have been developed by a variety of companies and there is not a single, uniform thermal desorber design. Different designs will effect project economics, regulatory requirements and performance efficiencies.

Thermal desorption treatment temperature ranges from 150° to 550°C (300° to 1000°F). Treatment operating temperatures are dependant upon the volatility of the target contaminant(s) present in the soil. A low temperature thermal desorption unit <350°C (<650°F) is effective in treating soil contaminated with a lighter volatile organic compound with a relatively low boiling point, (e.g. benzene boiling point 80°C (176°F)), a high temperature thermal desorption unit >340°C (>650°F) is suitable for treatment of soil organic compounds with low volatility classified as semi-volatile with a heavier contaminant such as chrysene (boiling point = 448°C (838°F)).

Currently there are numerous commercially available thermal desorption units. Each system contains unique components. Based on system design, thermal desorbers can also be classified into the following general categories:

- Direct Fired Thermal Desorbers (e.g. Direct Rotary Dryers, Conveyor Furnace Dryers);
- Indirect Heated Thermal Desorbers (e.g. Thermal Services, Indirect Rotary Dryer);
- Off-gas handling systems which condense the desorbed constituents or off-gas handling systems which burn the desorbed constituents in an afterburner; and
- Off-gas handling systems which use carbon adsorption or ion exchange technology.

The design team is not required to design or build a thermal desorption unit, however important design analysis and considerations are necessary.

During the remediation of any HTRW site the design engineer must keep in mind that all project activities must be protective of human health (including onsite workers) and the environment. With this in mind, planning an effective program for the remediation of contaminated material using a thermal desorber requires that specific attention be given to the following issues:

- Coordination with the appropriate regulatory agencies;
- Health and Safety (ER 385-1-92);
- Chemistry (ER 1110-1-263);
- Achieving performance criteria or remediation requirements;
- Air emissions controls;
- Site Closure
- Providing complete bid package for contractors;
- Construction Activities required to bring a thermal desorber to a site;

In order to coordinate all the activities listed above, the design engineer will need to refer to a number of existing Corps documents.

The sites which the design engineer will encounter will typically fall into two categories:

- Hazardous waste site; and
- Non hazardous waste sites (typically fuel oil or gasoline releases).

Remedial activities shall be coordinated with the appropriate state and federal regulators, regardless of the site classification.

Based on location and use, desorber units fall into the following two categories:

- Onsite Units - these units include both skid mounted and transportable thermal desorbers;
- Offsite Units.

The following subsections discuss these types of units in greater detail.

2.1 Onsite Thermal Desorption Units. Under CERCLA, an onsite thermal desorption unit would be defined as a unit which only accepts waste from the site where it is located. Under Section 121(e) of CERCLA, the desorption unit would not be required to have a RCRA permit, and once remediation is completed would be dismantled and transported to a different site.

2.2 Offsite Thermal Desorption Units. An offsite thermal desorber would be a unit which receives wastes from multiple sites and is permitted under RCRA. A facility might construct a thermal desorber for a particular hazardous waste site and then use the desorber to treat waste from other sites. The desorber under those conditions would be considered an offsite unit.

3. Theory. Thermal desorption is a process in which contaminated material are heated and the moisture and organic contaminants evaporated. This can be accomplished by heating the contaminated material to a temperature at which the constituents will not burn but will volatilize. Thermal desorption can also be accomplished by heating the contaminated material at higher temperatures in an oxygen deprived atmosphere that prevents combustion (Troxler, Cudahy, et al, 1993).

Figure B-1 is a general schematic of the thermal desorption process. In most cases, the contaminated material is agitated inside the desorber. The most common desorber units are rotary kilns (rotary dryers) and augers (thermal screw).

Systems can be directly fired, in which the contaminated material is desorbed in the same zone as the heating flame or indirectly fired, in which the heat is applied to the outside the shell of the desorber, with heat transferred to the contaminated material by conduction (Troxler, et. al., 1993).

Oil heated thermal screw systems consist of the following components: a solids pretreatment and feed system; an indirect heated screw(or auger); a heat transfer fluid heating system; a cooling conveyor for treated solids; an off-gas treatment system; and a water treatment system. The thermal screw systems are heated by circulating a hot heat transfer fluid (oil or steam) through the covered trough in which the screw rotates. The oil or steam is also circulated through the hollow auger flights and subsequently returned to the hollow auger shaft to heat the transfer fluid system (Troxler, et. al., 1993).

Energy equal to the heat capacity of the contaminated material multiplied by the change in temperature is used to heat a specific organic contaminant to its boiling point. Additional energy equal to the heat of vaporization of the specific organic contaminant is used to boil off or volatilize this contaminant. Prior to the volatilization of the specific contaminant, initial energy is required at the onset of treatment to vaporize water present in the contaminated material. The moisture content of the soil will impact the energy required to heat the soil due to the initial energy required to vaporize water; the heat of vaporization of the water may be significant. Additional energy is also required during the process to make up system heat losses. This process is continued until the organic contaminants are distilled from the contaminated material. The off-gas is maintained below the combustion threshold which is a function of: temperature, pressure, and oxygen concentration (US EPA, 1994).

After volatilization, organic constituents are either condensed, adsorbed or destroyed in a secondary device such as an afterburner or catalytic oxidation unit. Systems that condense and collect the volatilized organics produce a liquid waste stream that is generally treated or destroyed off-site. Adsorption media may be regenerated or incinerated, on or off-site. Systems that destroy the volatilized organics in a secondary device, such as an afterburner or a catalytic afterburner, must be tested to ensure destruction of the volatilized constituents is performed in accordance with applicable state and federal regulations. The off-gas can also be treated by adsorption on activated carbon or ion exchange media (EPA, 1988).

The critical design parameters for thermal desorption include required temperatures and retention times for adequate treatment and design of gas phase control/recovery systems. The required bed temperature and residence times depend to a large extent on the types of contaminants and soil or solid matrix being desorbed.

3.1 Direct Fired Units. Direct fired desorber units can supply heat to a waste using the following methods:

- Heat is supplied to a waste by contact with a hot gas which is heated by a flame; or
- Heat can be radiated (Infrared Thermal Desorber) onto the contaminated material.

Some infrared units use silicon carbide elements to generate thermal radiation beyond the red end of the visible spectrum. Materials to be treated pass through the unit on belts and are exposed to the radiation. Off-gases pass into a secondary chamber for further infrared irradiation and increased retention time to volatilize any contaminated particular matter present in the off gas.

3.2 Indirect Fired Units. Indirect fired desorber units can supply heat to a waste using the following methods:

- A desorption chamber can be heated indirectly at its surface by hot combustion gases that do not contact the contaminated material; or
- A desorption chamber can be heated indirectly by contact with a thermal screw that is heated with hot oil or another heat transfer fluid such as molten salt.

In either case, the vaporized constituents are removed by a carrier gas such as nitrogen. In most indirectly fired thermal desorption systems, the carrier gas is recirculated (US EPA, 1994).

Soils are transported through indirect fired units (thermal screws) by movement along the flights of the spinning auger or paddles and the auger trough. Use of this material transport

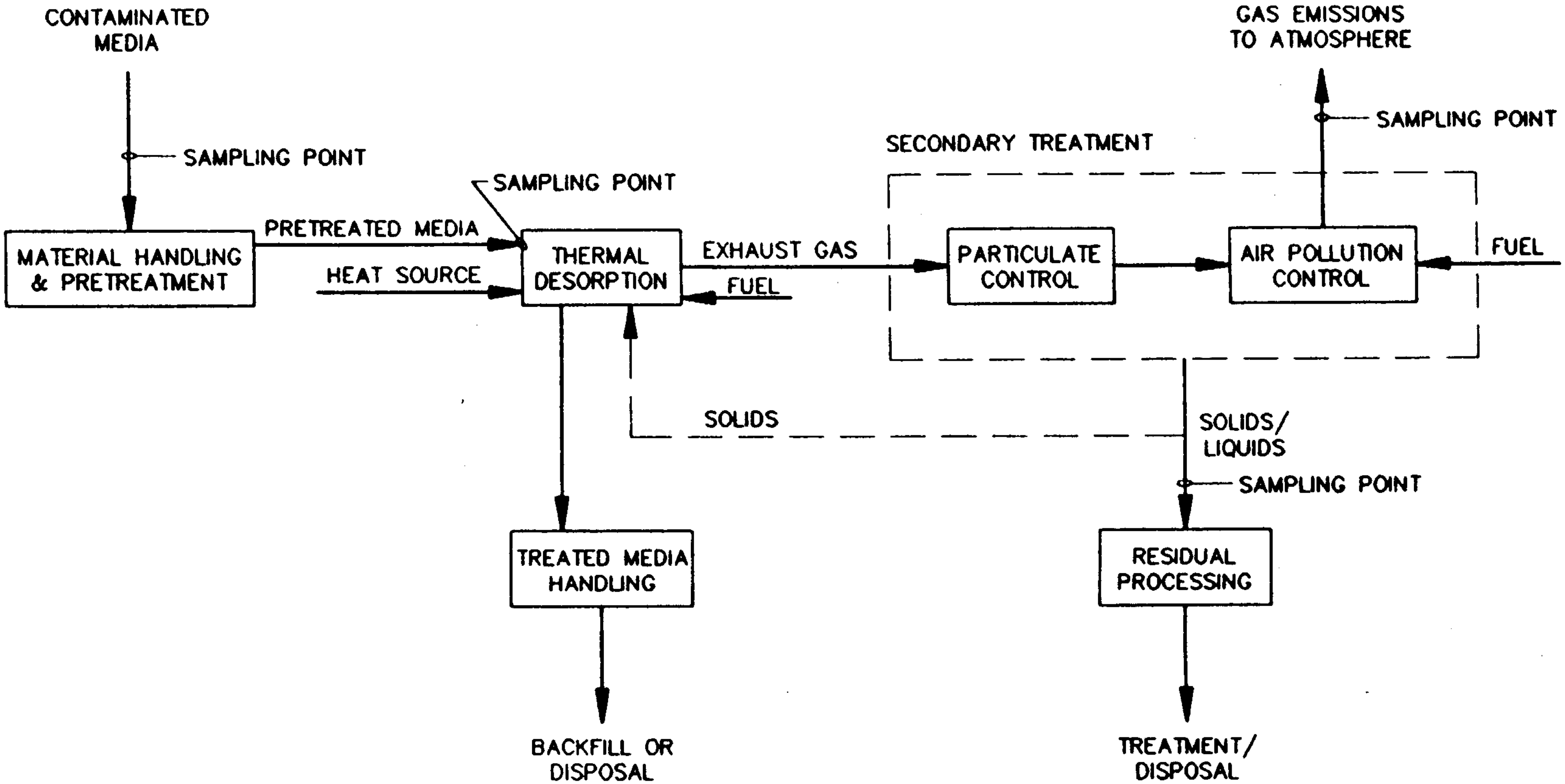

FIGURE B-1

THERMAL DESORPTION SYSTEM SCHEMATIC

system allows for the mixing, movement and heating of the contaminated material (Troxler, et. al., 1993). Some indirect fired units radiate the heat into a thin layer.

3.3 Transportable Units. When considering a transportable thermal desorption unit it should be understood that while the unit has been designed, constructed, and in many cases demonstrated to be effective at other waste sites, it is subject to site or contaminant specific permitting requirements. The transportable unit which has demonstrated its effectiveness to treat soil with a particular contaminant at one site may face different regulatory requirements hence design or operational modifications may be required at a second site with the same constituent. Furthermore, varying contaminated material constituents from site to site may impact treatment effectiveness and desorption unit performance. As a result design changes to the unit may be required to meet changing performance requirements. It is not uncommon to modify the air emissions control system from site-to site.

4. Definitions. Contaminated Material - Soil, sludge or sediment contaminated with hazardous and non- hazardous chemicals. Chemicals which have been successfully treated using thermal desorption are presented on Tables B-1 and B-2. The tables are based upon current available information related to demonstrated effectiveness at some scale of treatability testing or potential effectiveness of desorption to effectively remove the contaminant from the media.

Remediation Goals - Final concentrations of the constituents remaining in the media. Remediation goals should be established prior to starting design.

5. Objectives. The objective of this document is provide the design engineer or construction manager with information which is unique to the execution of a thermal desorption remediation project. The letter is based on an extensive review of Department of Defense agency documents, EPA, literature, and contractor information.

TABLE B-1
Effectiveness of Thermal Desorption on General Contaminant Groups for Soil, Sludge, Sediments, and Filter Cakes (for Low Temperature Units)

Contaminant Groups		Effectiveness			
		Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated Volatiles	■	▲	▲	■
	Nonhalogenated volatiles	■	▲	▲	■
	Organic cyanides	▲	▲	▲	▲
Inorganic	Volatile cyanides	■	▲	▲	▲

■ Demonstrated Effectiveness: Successful treatability test at some scale completed

▲ Potential Effectiveness: Expert opinion that technology will work

X No Expected Effectiveness: Expert opinion that technology has no expected effectiveness for treatment of the following contaminant groups: Organic corrosives, nonvolatile metals, asbestos, radioactive materials, inorganic corrosives, inorganic cyanides, oxidizers and reducers; contaminant groups PCBs, pesticides and furans are more appropriately heated in a high temperature unit.

Source: EPA Engineering Bulletin. Thermal Desorption Treatment. EPA/540/5-94/501.

TABLE B-2

Effectiveness of Thermal Desorption on General Contaminant Groups for Soil, Sludge, Sediments, and Filter Cakes (for High Temperature Units)

Contaminant Groups		Effectiveness			
		Soil	Sludge	Sediments	Filter Cakes
Organic	Halogenated semivolatiles	□	□	▲	□
	Nonhalogenated semivolatiles	□	▲	▲	□
	PCBs	□	▲	□	▲
	Pesticides	X	▲	▲	▲
	Dioxins/Furans	X	▲	▲	▲

□ Demonstrated Effectiveness: Successful treatability test at some scale completed

▲ Potential Effectiveness: Expert opinion that technology will work

X No Expected Effectiveness: Expert opinion that technology will not work

Source: EPA Engineering Bulletin. Thermal Desorption Treatment. EPA/540/5-94/501.